Specific Heat Capacity – Mixture Problems

Note that a measurement of 0°C is an 'exact value'.

1. A mixture is made by adding 0.100 kg of water at 95.0 °C to some water at 5.00 °C. The final temperature of the mixture is10.0°C. Determine:

   a) the heat lost by the hot water.

$Q = ?$
$m = 0.100\,kg$
$c = 4200\,J/kg\,°C$
$T_i = 95.0°C$
$T_f = 10.0°C$

$Q = mc\Delta T$
$Q = 0.100\,kg\,(4200\,J/kg\,°C)(10.0°C - 95.0°C)$
$Q = -35700\,J$

   b) the heat gained by the cold water.

$Q_1 = -Q_2$
$\therefore +35700\,J$

   c) the mass of the cold water .

$m = ?$

$Q = mc\Delta T$
$\frac{Q}{c\Delta T} = m$

$m = \frac{35700\,J}{4200\,\frac{J}{kg\,°C}(10.0°C - 5.00°C)}$
$m = 1.70\,kg$

2. 1.00 kg of water at 80.0 °C is added to 2.00 kg of water a 50.0 °C. What is the final temperature of the mixture?

3. 1.00 kg of paraffin oil at 70.0 °c is added to 1.00 kg of water at 40.0 °C. What is the final temperature of the mixture? 50.0°C

$T_f = ?$
$m_p = 1.00\,kg$
$T_{ip} = 70.0°C$
$C_p = 2100\,J/kg\,°C$
$m_w = 1.00\,kg$
$T_{iw} = 40.0°C$
$C_w = 4200\,J/kg\,°C$

$Q_p = -Q_w$
$m_p C_p (T_f - T_{ip}) = -m_w C_w (T_f - T_{wi})$
$T_f = \frac{m_w C_w T_{iw} + m_p C_p T_{ip}}{m_p C_p + m_w C_w}$

$T_f = \frac{1.00\,kg\,(4200\,\frac{J}{kg\,°C})(40.0°C) + 1.00\,kg\,(2100\,\frac{J}{kg\,°C})(70.0°C)}{1.00\,kg\,(2100\,J/kg\,°C) + 1.00\,kg\,(4200\,J/kg\,°C)}$
$T_f = 50.0°C$

4. A piece of iron at 3.00 °c is dropped into a bucket containing $\mathbf{1\overline{0}}$ kg of water at $\mathbf{9\overline{0}}$ °C. The final temperature of the mixture is 45.5 °C. Find the mass of the iron.

$m_I = ?$
$T_{iI} = 3.00°C$
$C_I = 460\,J/kg\,°C$
$m_w = 10\,kg$
$C_w = 4200\,J/kg\,°C$
$T_{iw} = 90°C$
$T_f = 45.5°C$

$Q_w = -Q_I$
$m_w C_w (T_f - T_{iw}) = -m_I C_I (T_f - T_{iI})$
$m_I = \frac{m_w C_w (T_f - T_{iw})}{-C_I (T_f - T_{iI})}$

$m_I = \frac{10(4200)(45.5 - 90)}{-460(45.5 - 3.00)}$
$m_I \simeq 96\,kg$

5. A piece of aluminum at 14.0 °C is dropped into 5.00 kg of antifreeze at 53.0 °C. If the final temperature of the mixture is 308 K, find the mass of the aluminum.

$m_a = ?$
$c_a = 900\ J/kg\,°C$
$T_{ia} = 14.0\,°C$
$m_f = 5.00\ kg$
$c_f = 2200\ J/kg\,°C$
$T_{if} = 53.0\,°C$
$T_F = 308\ K = 35.0\,°C$

$Q_a = -Q_f$
$m_a c_a \Delta T_a = -m_f c_f \Delta T_f$
$m_a = \dfrac{-m_f c_f \Delta T_f}{c_a \Delta T_a}$

$m_a = \dfrac{-5.00\ kg\,(2200)(35.0 - 53.0)}{900\,(35.0 - 14.0)}$

$m_a \approx 10.5\ kg$

6. 5.00 kg of ethanol at 75.0 °C is added to 2.00 kg of water at 30.0 °C. Find the final temperature of the mixture.

7. A solid object with a mass of 5.00 kg at a temperature of 88°c is placed into 8.88 kg of methanol at 0°C. The final temperature of the mixture is 8.00 °C. Find the specific heat of the object and identify it.

$T_F = 8.00\,°C$
$m = 5.00\ kg$
$T_i = 88\,°C$
$c = ?$
$m_m = 8.88\ kg$
$T_{im} = 0\,°C$
$c_m = 2500\ J/kg\,°C$

444 J/kg°C Iron

$Q = -Q_m$
$mc\Delta T = -m_m c_m \Delta T_m$
$c = \dfrac{-m_m c_m \Delta T_m}{m \Delta T}$

$c = \dfrac{-8.88\ kg\,(2500\ J/kg\,°C)(8.00\,°C - 0\,°C)}{5.00\ kg\,(8.00\,°C - 88\,°C)}$

$c = 444\ J/kg\,°C$

Iron

8. An unknown liquid with a mass of 2.00 kg and having a temperature of 1.00 °C is mixed with 1.00 kg of water at 53.3 °C. The final temperature is 50.0 °C. Find the specific heat capacity of the unknown liquid and then identify it.

9. What mass of zinc at 20.0 °C must be added to 5.00 kg of silver at 80.0 °C to achieve a mixture at 60.0°C?

10. In an experiment, 200 g of gold at 95.0 °C is mixed with 50.0 g of an unknown substance at 21.4 °C. The final temperature was 50.0 °C. What was the unknown substance? 818 J/kg°C Sand

$c = ?$
$m_g = 0.200\,kg$
$T_{ig} = 95.0°C$
$m = 0.0500\,kg$
$T_i = 21.4°C$
$C_g = 130\,J/kg°C$
$T_f = 50.0°C$

$Q = -Q_g$

$mc\Delta T = -m_g C_g \Delta T_g$

$c = \frac{-m_g C_g \Delta T_g}{m \Delta T}$

$c = \frac{-0.200kg\,(130\,\frac{J}{kg°C})(50.0°C - 95.0°C)}{0.0500\,kg\,(50.0°C - 21.4°C)}$

$c \approx 818\,J/kg°C$

$\therefore$ Sand

11. In doing a heat exchange lab, we forgot to measure the initial temperature of the water. We do know that we added 15.0 kg of brass to 1.00 kg of water and the temperature of the brass dropped 50.0 °C. If the final temperature of the mixture was 77.0 °C, what was the initial temperature of the water? 9.14 °C

$m_b = 15.0kg$
$m_w = 1.00kg$
$T_f = 77.0°C$
$\Delta T_b = -50.0°C$
$T_{iw} = ?$
$C_w = 4200\,J/kg°C$
$C_b = 380\,J/kg°C$

$Q_w = -Q_b$

$m_w C_w (T_f - T_{iw}) = -m_b C_b \Delta T_b$

$T_f - T_{iw} = \frac{-m_b C_b \Delta T_b}{m_w C_w}$

$T_{iw} = \frac{m_b C_b \Delta T_b}{m_w C_w} + T_f$

$T_{iw} = \frac{15.0kg\,(380\,\frac{J}{kg°C})(-50.0°C)}{1.00kg\,(4200\,J/kg°C)} + 77.0°C$

$T_{iw} \approx 9.14°C$

12. When 10.0 kg of antifreeze at 20.0 °C is added to 1.50 kg of water at 85.0 °C, what is the final temperature of the mixture? 34.5°C

$T_f = ?$
$m_a = 10.0kg$
$T_{ia} = 20.0°C$
$C_a = 2200\,J/kg°C$
$m_w = 1.50kg$
$T_{iw} = 85.0°C$
$C_w = 4200\,J/kg°C$

$Q_a = -Q_w$

$m_a C_a (T_f - T_{ia}) = -m_w C_w (T_f - T_{iw})$

$T_f = \frac{m_w C_w T_{iw} + m_a C_a T_{ia}}{m_a C_a + m_w C_w}$

$T_f = \frac{1.50kg\,(4200\,\frac{J}{kg°C})(85.0°C) + 10.0kg\,(2200\,\frac{J}{kg°C})(20.0°C)}{10.0kg\,(2200\,J/kg°C) + 1.50kg\,(4200\,J/kg°C)}$

$T_f \approx 34.5°C$

13. How much helium at 4.00 °C do you need to add to 20.0 kg of hydrogen at 60.0 °C to produce a temperature change of -30.0 °C? The specific heat of helium is 5193 kJ/kg°C.

14. Starting with 10.0kg of ice at-20.0 °c, we add 3.28 kg of an unknown substance at 25.0°C. The final temperature of the mixture is -15.0 °C. What is the unknown substance? 800 J/kg°C Sand

$m_I = 10.0kg$
$T_{iI} = -20.0°C$
$C_I = 2100\,J/kg°C$
$m = 3.28kg$
$T_i = 25.0°C$
$c = ?$
$T_f = -15.0°C$

$Q = -Q_I$

$mc\Delta T = -m_I C_I \Delta T_I$

$c = \frac{-m_I C_I \Delta T_I}{m \Delta T}$

$c = \frac{-10.0kg\,(2100\,J/kg°C)(-15.0°C - (-20°C))}{3.28kg\,(-15.0°C - 25.0°C)}$

$c \approx 800\,J/kg°C$

$\therefore$ Sand

15. What is the final temperature of a mixture of2.20 kg of carbon at 20.0 °c and 3.00 kg of copper at 100°C? 54.3°C

T_F = ?
$m_c = 2.20\,kg$
$T_{ic} = 20.0°C$
$C_c = 710\ J/kg°C$
$m_{cu} = 3.00\,kg$
$T_{icu} = 100°C$
$C_{cu} = 390\ J/kg°C$

$Q_c = -Q_{cu}$

$m_c C_c (T_F - T_{ic}) = -m_{cu} C_{cu} (T_F - T_{icu})$

$T_F = \dfrac{m_{cu} C_{cu} T_{icu} + m_c C_c T_{ic}}{m_c C_c + m_{cu} C_{cu}}$

$T_F = \dfrac{3.00kg\left(390\frac{J}{kg°C}\right)(100°C) + 2.20kg\left(710\frac{J}{kg°C}\right)(20.0°C)}{2.20kg\left(710\frac{J}{kg°C}\right) + 3.00kg\left(390\frac{J}{kg°C}\right)}$

$T_f \approx 54.3°C$

16. What is the temperature change produced in 5.0 kg of uranium if 10.0 kg of oxygen at 0.60 °C is passed over it? The final temperature of the oxygen is 6.00 °C.

17. What mass of nitrogen at 60.0 °c must be added to 20.0 kg of magnesium at 35.0 °c to achieve a mixture at 40.0°C?

18. If we add 9.30 kg of paraffin oil to 5.00 kg of ethanol, the temperature of the oil is 220 K. The final temperature of the mixture is 7.00 °C. What was the initial temperature of the ethanol?

19. A **500** g glass is heated to **150** °C and filled with sand at 20.0 °C. If the final temperature of the mixture is 50.0 °C, what was the mass of the sand? 1.25 Kg

$m_g = 0.50\,Kg$
$T_{ig} = 150°C$
$C_g = 600\ J/kg°C$
$T_{is} = 20.0°C$
$m_s = ?$
$C_s = 800\ J/kg°C$
$T_f = 50.0°C$

$Q_s = -Q_g$

$m_s C_s \Delta T_s = -m_g C_g \Delta T_g$

$m_s = \dfrac{-m_g C_g (T_F - T_{ig})}{C_s (T_F - T_{is})}$

$m_s = \dfrac{-0.50kg\left(600\ J/kg°C\right)(50.0°C - 150°C)}{800\ J/kg°C\ (50.0°C - 20.0°C)}$

$m_s = 1.25\,Kg$

20. A 750 g sample of rubidium is heated to 125°C. When it is dropped into 7.43 kg of liquid at 69.0 °C a mixture with a temperature 70.0 °C forms. What was the liquid?

21. What is the final temperature of a mixture made from 5.00 kg of platinum at 150°C and 5.00 kg of ice at -95.0°C?